III. *Comets whose Perihelion Distances are Greater than* 0.05 *and Less than* 0.1.

Perihelion Passage.	*Per. Dist.*	*Long. of Per.*
1. 1593, July 18*d.* 13*h.*	0.0891	176° 19′
2. 1780, Sept. 30 22	0.0963	246 35
3. 1821, March 21 12	0.0918	239 29

With greater perihelion distances the tendency of the perihelia to crowd together around the point indicated is less distinctly marked.

8. Few comets of small perihelion distance should have their perihelia in the vicinity of longitude 80°, the point opposite that towards which the sun is moving. Accordingly we find, by examining a table of cometary elements, that with a perihelion distance less than 0.1, there is not a single perihelion between 35° and 125°; between 0.1 and 0.2, but 3; and between 0.2 and 0.3 only 1.

Bloomington, Indiana, *September* 14*th*, 1869.

A SEARCH FOR A NORMAL CAUSE OF THE RECESSION OF COSMICAL NODES.

By Hon. Walter H. Lowrie.

Read before the American Philosophical Society, Nov. 19, 1869.

The analogy between the recession of the nodes of all the planets and satellites of the solar system, including that of the earth, called the precession of the equinoxes, is so complete and manifest that the mind, on the discovery of it, naturally inclines to attribute them all to like causes. These phenomena have not been so treated heretofore, but have been regarded as disturbances produced by various causes, the influence of which I do not feel entitled to question, while I think there is a normal cause which ought to be considered.

It seems to me to be a proposition of axiomatic plainness, that, in any system or sub-system of moving bodies, all its periodic motions ought to be presumed normal, rather than abnormal, that is, the causes of them ought to be first sought in the plan of the system itself; and only when this search fails ought we to suspect them to be disturbances caused by forces which are alien to the system. Thus, all the periodic motions of the planets ought to be presumed to depend on their relation to the sun, until the contrary appears; and all the periodic motions of the satellites ought to be presumed to depend upon their several planets.

Our scientific systems consist only of the elements from which, and of the order by which we construct them, and are, therefore, charged with all the defects of our knowledge and constructive skill. In the early stages of astronomy, many phenomena were treated as exceptional and disturbing, which are now known to be normal pulsations of the *vis viva* of the solar system, because now this force is better comprehended. And the same is true of all growing sciences. All our scientific systems are accustomed to discover that their ideals of nature are often very unreal, and that the perturbations, which they attribute to nature, belong only to themselves. Newly discovered facts or principles must always cause some derangement or re-arrangement of the old furniture of the school that admits them.

Now that we know that the solar system is a part of a much grander system, in which the sun itself revolves, we have a fact which is, in many respects of great astronomical importance, and which did not enter into the inductions of former times; and considering its character, it is not unnatural to suppose that it is an essential element in all the motions of the system. If this be so, then our whole system of astronomical dynamics must, to some extent, open up to admit its influence and to submit to such modifications as it may require.

This fact can no more be without influence on the motions of the planets, than can be the revolution of the planets on their satellites. It necessarily made a great change in our knowledge of the form of planetary orbits, though it may not greatly change our reasoning about them. And yet, what is the parallax of a star worth to us now, unless we know whether the sun's motion (say 150,000,000 miles a year) was taken into account, and whether the base of the parallactic angle was 190,000,000 + 75,000,000 miles, or 190,000,000—75,000,000, or some chord of intermediate length? How, without this, shall we value any ancient observation of the place of a star, or the record of stellar movements supposed to be made in the construction of the pyramids? It may now be thought better to take one, or ten, or more years of the sun's motion in the base of such an angle.

Such changes in scientific theories do not often make any serious changes in the laws which observation had discovered as facts, but rather account for them, and show the common bond that unites them in nature and in reason. When the centre of cosmical motion was transferred from the earth to the sun, the laws of the solar system, as they had been learned before, were not annulled. When light changed its base from EMISSION to UNDULATION, the laws of optics were not seriously affected. A law may be true as an expression of observed phenomena, even when its principle is unknown or mistaken, or when it is erroneously supposed to be itself a final and independent principle.

I think the normal cause, not to speak of disturbing ones, of the recession of the nodes can be found in the system or sub-system to which the motion belongs, and that it is the same everywhere. It seems to me to be a necessary consequence of the inclination of the dependent to the

principal orbit, and, so far as we know, this form pervades the whole solar system.

True, we know not yet the direction of the real orbit of the sun, and, therefore, cannot tell how the other orbits are inclined to it. But we know that all the others have different inclinations, and that, therefore, not more than one, and probably none, of them coincides with the sun's. And if the observations of Sir William Herschel and his successors, on the course of the sun, are near the truth, then it is proved that all are so inclined; and we do not mark recessions on the sun's orbit because we have not yet found where it is. Finding the law that recession of nodes always accompanies their existence, we naturally expect a like cause for all cases, a cause growing out of like relations to the main force of the system or sub-system; and therefore we ought to study how the central force operates on a dependent body moving in that form.

Let us be sure, even at the risk at an unnecessary presentation of rudiments, that we have a right possession of this phenomenon of the recession of the nodes, and that it is a phenomenon of the earth's motion. It is, of course, difficult for a person unused to the study of the motions of the solar system to form or retain very clear conceptions of all their changing complications. He will often be mistaken in his geometry of the heavens, and may seldom have the pleasure of more than a transient confidence in his conceptions about it. Occupying a revolving and rotating position, and obliged to find from it the courses and velocities of the shifting currents of the cosmical ocean, and fix them by the floating landmarks of the skies, he will often get confused and suspect himself incompetent.

We shall not need to go beyond the instances of the earth and moon to get illustrations of this motion sufficient to show its unity of form and unity of relation to the central body. It is involved in the geometrical conception of a cosmical system, that, where its orbital planes differ in inclination, each must internode with all the others by a line passing through their common centre, and this is the line of its nodes. But if the planes always maintained the same direction in space, there could be no motion of nodes, and these cross-roads of the skies would be less important and interesting than they now are.

It is admitted that the axes of rotation of all the planets and satellites, except the earth, are fixed and stable, so that they change direction only *with* their orbital planes and not *in* them, and it is supposed that the earth alone tilts *in* its plane. It is admitted also that all these planes except the earth's have a constant warping or tilting motion westward, and that their bodies tilt *with* them, and this causes these planes to cut through any fixed plane further westward in each revolution, and the lines of their nodes to recede on any such plane, and the ecliptic is taken as such a one; but it is supposed that a similar appearance is produced, relative to the earth, by a tilting of the earth itself *in* its plane, marked by its equator on the ecliptic, and not by a tilting *of* its plane. If this be so, then

the earth has the same tilt *in* the moon's plane also, and this would be a further anomaly.

Possibly these differences of statement may be accounted for from the fact, that, besides our ignorance of the sun's motion, the recession of nodes can have value for us only as the nodes are stations on the earth's orbital plane, and can be noted as crossings of this great highway; and, of course, the ecliptic can be no measure of its own inclination, or revolutions, or recession. Certainly the ecliptic does appear to have a tilting motion, completing a revolution in 25,868 years, so that the sun, in that time, will appear to pass over all the stars that are between the tropical circles. And why should we treat this as only an apparent motion of the earth's orbital plane, while admitting that it is real in all other cases?

It may help us here if we take notice of a class of cases wherein there is a real tilting of the axis of rotation of a body *in* its orbital plane. They are all cases where a body moves in two planes at once; as a planet with a satellite, having an inclined orbit, where there is a conflict of two forces, represented by the two planes, and an accommodation between them. Here we assume that the earth, without the moon, would have no tilt or change of direction of its axis *in* its own plane. But it is also in the moon's plane, and this has a tilting revolution round the earth in 19 years. Then this relation of the earth and moon is analogous to their connection by a lever, representing their mutual attraction in the line of the moon's nodes, the fulcrum being their common centre of gravity. If the earth's axis had a fixed position on this lever, it would go with it, and thus have a real tilt *in* its own plane equal to double the inclination of the moon's plane. But it is held by the greater force represented by its own plane and its centre, so that this tilt is very small, called its nutation, having a period of nineteen years, and being only another aspect of the revolution of the moon's nodes. It would perform an ellipse round the ideal pole of the heavens; but, by its combination with the greater motion of the earth's pole by the recession of *its* nodes, it becomes a series of 19-year scollops in that ellipse. Here is a case and a cause of tilting *in* a plane, which no doubt exists in all planets which have satellites, and even in the sun itself, and I think that no other such a case is known to astronomy.

We know of no cosmical cause for this fixedness of axes of rotation; but, without it, we could have no science of astronomy, no measure of time, no measure of direction or position beyond the earth itself; for upon this depends, directly or indirectly, all our astronomical measures. If the earth's orbital plane tilts and revolves, and thus changes the direction of the earth's axis, it is with so slow a movement as not to embarrass the observations and calculations of a human lifetime, and scarcely those of human history, but only to mark those immense periods by which eternity is terraced off before and behind us. If this plane does thus revolve, and if its axis is inclined to the axis of the earth, no matter what may be the dip of its tilt, the poles of the two axes will revolve around each other, and always maintain to each other the same angle of incli-

nation, unless there be some cause that affects the fixedness of one of them.

We are to seek the cause of recession of nodes in a system so constructed and so operating, by the force of cosmical attraction, that this very force will appear to be the cause, and that we may see its mode of operation, if it be really there. To illustrate such a structure, we may take any planet or satellite of the solar system ; for all alike have this cosmical force and this inclination of orbital plane, and this recession of nodes.

We take the moon in its revolution. Because of this inclination, one half of its orbit is above and the other half below the plane of the earth's orbit. While the earth is sweeping around in its great orbit, it swings the moon around it, as upon an epicycle of which the earth is the centre. A proper conception of these two motions in relation to each other gives us the direction of the central force which produces the moon's motion.

It is never directed from a point fixed as the centre of the orbit, nor from a straight line, constituted by a motion of such a point, but from a centre always moving in a line curving eastwardly, and in a direction differing from that of the moon's orbit according to the different inclinations of the earth's and the moon's orbits. It is the very force which bears the moon forward in space, and yet, by reason of the form of their connection, it is always moving laterally and eastwardly out of the centre of the moon's plane, and tending also to push forward through and beyond the plane, and thus it is all the while exerting its force in a sort of twisting of the moon's orbit into perpetual accommodation to the curve of the orbit of its primary.

The result of this is, that no matter what may be the position of the moon's plane, this force, always departing from a right line, constantly draws the moon down or up through the plane of the earth's orbit sooner in each successive revolution ; and this is equivalent to a westward warping or tilting motion of the moon's plane, so that it cuts that of the earth more and more westward in each revolution ; and this would constitute a constant recession of the nodes, even if there were no other causes of it ; and it ought not to be overlooked.

If this is a correct reading of this force and its dependent motions, which I submit to those who may consider the subject worth thinking about, then the central force of every planet operates in precisely the same form on its satellites, where their orbital planes are inclined, varied only according to their degrees of inclination. And, of course, the sun (assuming its motion to be as heretofore stated) operates in the same way upon all the planets, so as to produce a recession of their nodes ; and the phenomenon of recession of nodes, even if not entirely normal, has a perfectly normal cause.

It follows also, that wherever we find a constant recession of the nodes of a secondary body, we may naturally infer that its primary is itself revolving around some central body ; though it will be impossible to say that

this product of the central force may not be entirely merged in the product of some disturbing force.

Dr. Whewell regards the discovery of the precession of the equinoxes, resulting from the attraction of the sun and moon on the earth's equatorial protuberance, as a remarkable example of the consilience of inductions; but surely this consilience is more impressive when we notice that that form of attraction is enterely singular, not being known to exist in any other, even analogous, case; whereas, the form here suggested applies to every case where there are revolving nodes; that it presents the motion as a perfectly normal consequence of the central force of each system or sub-system, operating directly upon its dependent body according to the relation of its orbit; and that it recognizes a physical, along with a formal, unity in the plan of the whole system, and satisfies the second of Newton's "Rules of philosophizing," that "Natural effects of the same kind are to be referred to the same cause, so far as can be done." The other theory has this difficulty to contend with: that we suppose all planets to have equatorial protuberances, as an effect of rotation; and, so far as we know, all have inclined axes; and yet we do not attribute to them precession of equinoxes and recession of nodes as two different motions. Both exist, but only as different aspects of the same motion.

But the views here presented are not without serious difficulty in their ulterior application. If the cause here suggested is true, then it seems natural to seek some proportion in time between the revolutions of the nodes and those of the central bodies on which they depend; a proportion modified by the differences of relation in space and time in which the several secondaries stand to their primaries. I do not discover the law of such a proportion, or even that it surely exists. If it were discovered it would probably be of use in seeking the period and orbit of the sun's revolution.

So far as our knowledge goes at present, we find that it always requires many revolutions of a planet or satellite for one revolution of its nodes, and they differ very greatly. In one revolution of its nodes Mercury revolves in its orbit over 500,000 times; Venus, 100,000; the earth, 25,000; Mars, 27,000; Jupiter, near 7,000; Saturn, 2,200; and Uranus, 428. No others revolve in so short a *time* as those of the earth. Among the satellites, the moon revolves 230 times for one revolution of its nodes; Jupiter's 2d satellite, 3,000; its 3d, 7,000; its 4th, 11,000 times.

And in all known cases the central body revolves more frequently than the nodes of its dependent. Thus the earth revolves in its orbit near 19 times for one revolution of the moon's nodes; Jupiter $2\frac{1}{2}$ times for once of the nodes of its 2d satellite, 12 times for its 3d, and 45 times for its 4th satellite. All this would seem to indicate a period for the sun's revolution round its unknown centre, which would be a very small fraction of any estimate of it that I have seen, founded on observations of stellar parallaxes. I find no clue to the solution of this apparent anomaly; I hope some other inquirer may.